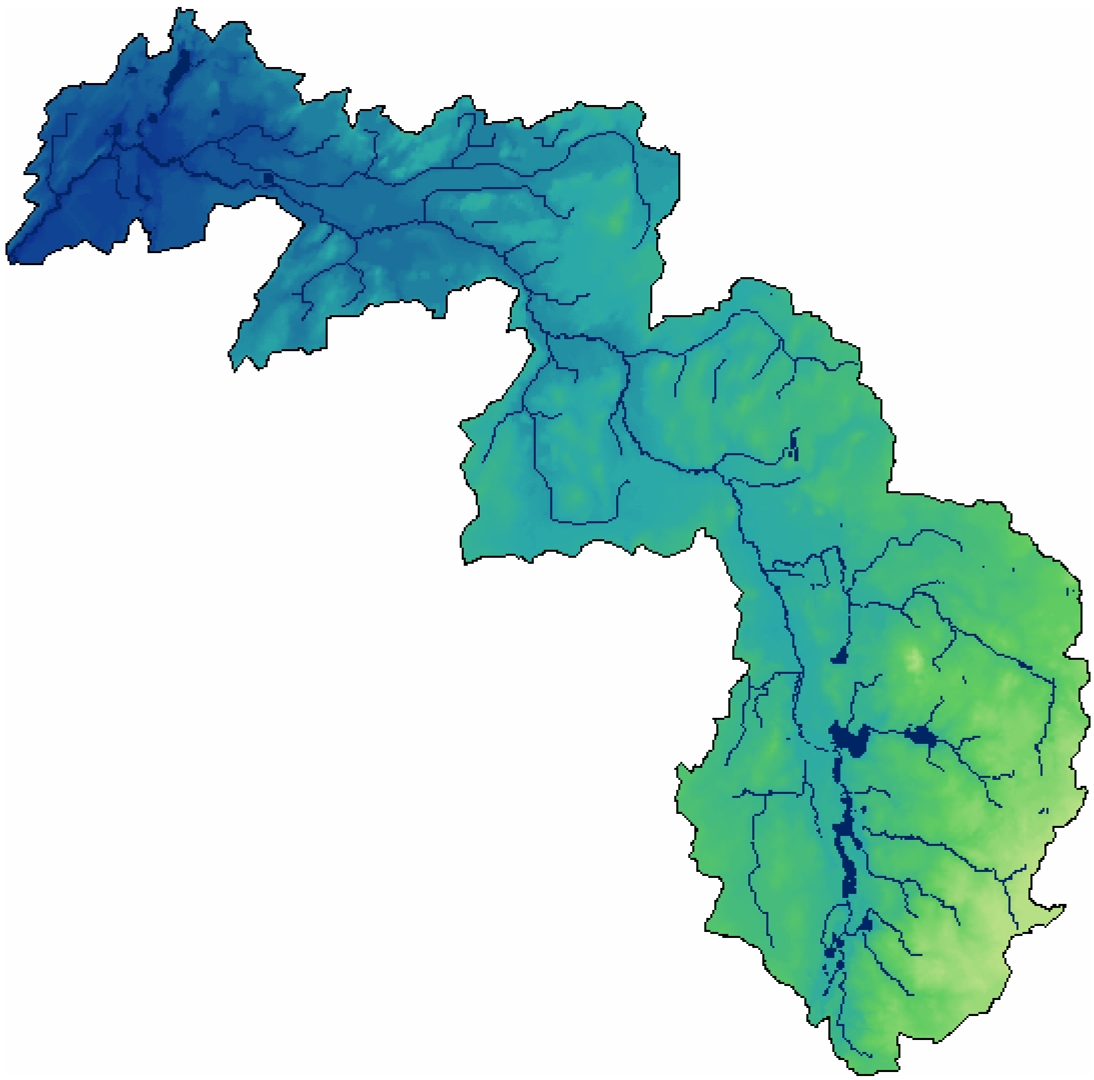
Hog Creek Watershed Hydrologic Study



Michigan's Nonpoint Source Program

Dave Fongers
Hydrologic Studies Unit
Land and Water Management Division
Michigan Department of Environmental Quality
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For comments or questions relating to this document, contact Dave Fongers at:

MDEQ, LWMD, P.O. Box 30458, Lansing, MI 48909
fongersd@michigan.gov
517-373-0210

Michigan's Nonpoint Source Program

The Hog Creek hydrologic study was funded by a Part 319 grant from the United States Environmental Protection Agency to MDEQ's Nonpoint Source program. For more information, go to www.michigan.gov/deqnonpointsourcepollution.

Summary

A hydrologic model of the Hog Creek watershed was developed by the Hydrologic Studies Unit (HSU) of the Michigan Department of Environmental Quality (MDEQ) using the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS). The hydrologic model was developed to help stakeholders better understand the watershed's hydrologic characteristics and the impact of hydrologic changes in the Hog Creek watershed. Watershed stakeholders may combine this information with other determinants, such as open space preservation, to decide what locations are the most appropriate for wetland restoration, stormwater detention, in-stream BMPs, or upland BMPs. The Hillsdale Conservation District can then incorporate this information into the Hog Creek watershed plan that it is developing. Local governments within the watershed could also use the information to help develop stormwater ordinances.

The hydrologic model has two scenarios corresponding to land uses in 1800 and 1978. General land use trends are illustrated in Figure 1. More detailed land use information is provided in Table 1 in the Watershed Description and Model Parameters section of this report.

The model shows increases in stormwater runoff volumes and peak flows from 1800 to 1978 for the 50 percent chance (2-year) and 4 percent chance (25-year) 24-hour design storms. The increases are due to changes in land use and loss of storage. Overall results are illustrated in Figures 10 through 13. Detailed data and discussion of the results are in the Model Results section of this report.

Increases in the runoff volume and peak flow from the 4 percent chance, 24-hour storms could cause or aggravate flooding problems unless mitigated through the use of effective stormwater management techniques. Increases in the 50 percent chance, 24-hour storm will increase channel-forming flows. The channel-forming flow in a stable stream usually has a one- to two-year recurrence interval. These relatively modest storm flows, because of their higher frequency, have more effect on channel form than extreme flood flows. Hydrologic changes that increase this flow can cause the stream channel to become unstable. Stream instability is indicated by excessive erosion at many locations throughout a stream reach. Stormwater management techniques used to mitigate flooding can also help mitigate projected channel-forming flow increases. However, channel-forming flow criteria should be specifically considered in the stormwater management plan so that the selected BMPs will be most effective. For example, detention ponds designed to control runoff from the 4 percent chance, 24-hour storm may do little to control the runoff from the 50 percent chance, 24-hour storm, unless the outlet is specifically designed to do so.

One way to compare runoff from different subbasins or watersheds is to calculate the yield, which is the peak flow divided by the drainage area. The area-weighted average yield from the 50 percent chance (2-year), 24-hour storm for the Hog Creek watershed is 0.02 cubic feet per second per acre (cfs/acre) for the 1978 land use scenarios. This

value may be used to guide stakeholders' stream stability management decisions. The area-weighted average yield from the 4 percent chance (25-year), 24-hour storm for the Hog Creek watershed is 0.05 cfs/acre for the 1978 land use scenario. This value may be used to guide stakeholders' flood control management decisions. Additional details are shown in Figures 14 and 15 and in the Model Results section of this report.

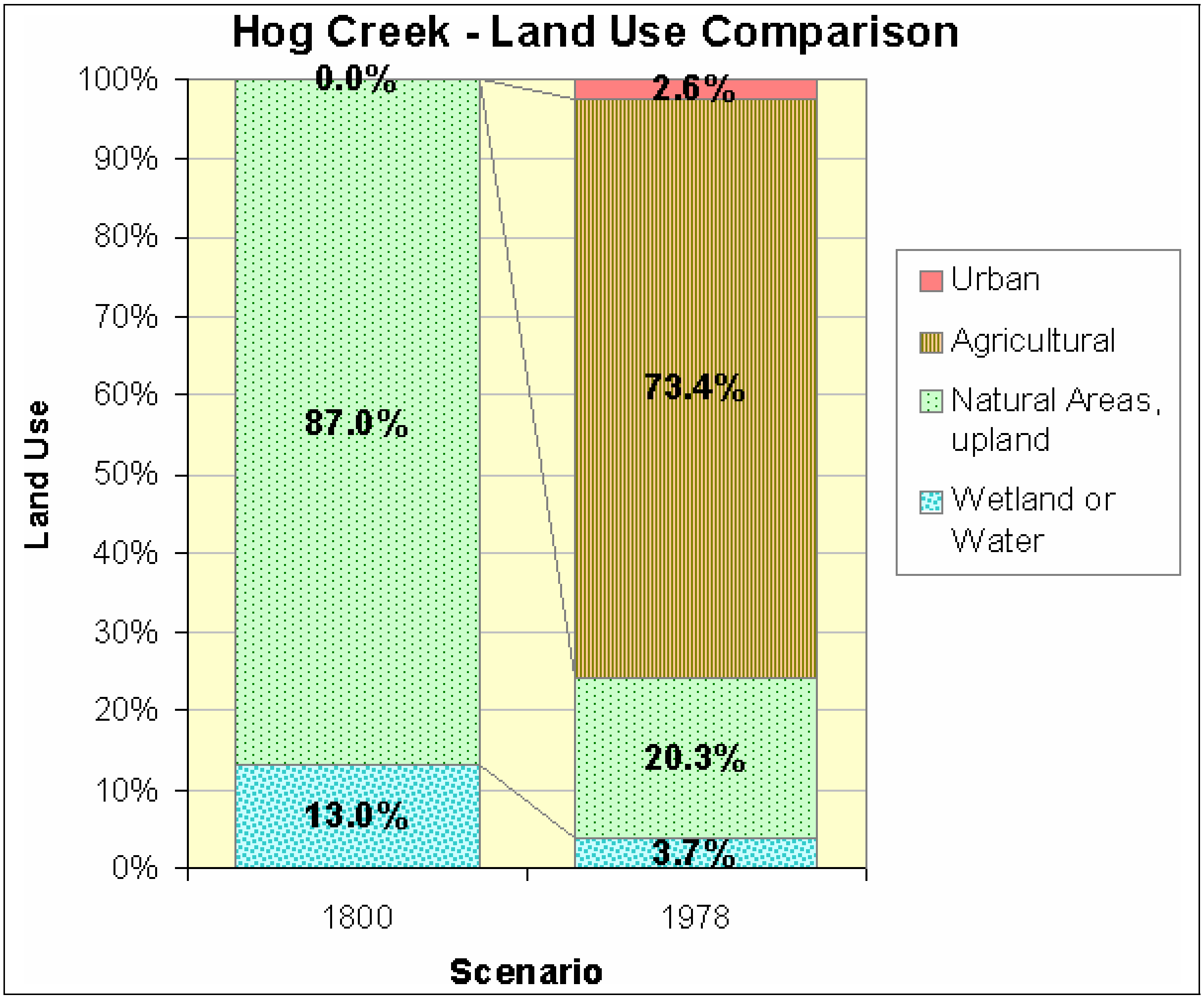

Figure 1: Land Use Comparison

Project Goals

The Hog Creek hydrologic study was initiated in support of the Hillsdale Conservation District, which is developing a watershed management plan for the Hog Creek watershed. This Hog Creek hydrologic study is funded by a United States Environmental Protection Agency (USEPA) Part 319 grant administered by the MDEQ. The goals of this Hog Creek study are:

- To better understand the watershed's hydrologic characteristics and the impact of hydrologic changes in the Hog Creek watershed
- To facilitate the selection and design of suitable BMPs

- To provide information that can be used by local units of government to develop or improve stormwater ordinances

- To help determine the watershed management plan's critical areas – the geographic portions of the watershed contributing the majority of the pollutants and having significant impacts on the waterbody

Watershed Description and Model Parameters

The 108 square mile Hog Creek watershed, Figure 2, outlets to the Coldwater River between Union City and Coldwater in Branch County. This Hog Creek study divides the watershed into eleven subbasins, as shown in Figure 3.

Hog Creek's profile, Figure 4, is basically typical, steeper in the headwaters and flatter toward the mouth. The steeper and flatter sections are separated by Carpenter and Long Lakes in Figure 4, which are part of a series of lakes locally referred to as the chain of lakes.

Our analysis of the watershed uses the curve number technique to calculate surface runoff volumes and peak flows. This technique, developed by the Natural Resources Conservation Service (NRCS) in 1954, represents the runoff characteristics from the combination of land use and soil data as a runoff curve number. The technique, as adapted for Michigan, is described in "Computing Flood Discharges For Small Ungaged Watersheds (Sorrell, 2003), www.deq.state.mi.us/documents/deq-glm-water-scs2003.pdf.

The curve numbers for each subbasin, listed in Appendix A, were calculated using Geographic Information Systems (GIS) technology from the digital land use and soil data shown in Figures 5 through 9. Land use maps based on the MDEQ GIS data for 1800 and 1978 are shown in Figures 5 and 6, respectively. The MDEQ Nonpoint Source program does not expect or recommend that the flow regime calculated from 1800 land use be used as criteria for BMP design or as a goal for watershed managers.

The NRCS soils data for the watershed is shown in Figure 7. Where the soil is given a dual classification, B/D for example, the soil type was selected based on land use. In these cases, the soil type is specified as D for natural land uses, or the alternate classification (A, B, or C) for developed land uses. The soils classifications used for each land use scenario are shown in Figures 8 and 9.

The runoff curve numbers calculated from the soil and land use data are listed in Appendix A. The time of concentration for each subbasin, which is the time it takes for water to travel from the hydraulically most distant point in the subbasin to the design point, was calculated from the United States Geological Survey (USGS) quadrangles. The storage coefficients, which represent storage in the subbasin, were iteratively adjusted to provide a peak flow reduction equal to the ponding adjustment factors detailed in Appendix A.

The reach routing method is the lag method. Lag is the travel time of water within each section of the stream. The method translates the flood hydrograph through the reach without attenuation. It is not appropriate for reaches that have ponds, lakes, wetlands, or flow restrictions that provide storage and attenuation of floodwater. Lag values for each reach were calculated using USGS quadrangles and are listed in Appendix A.

The selected precipitation events were the 50 and 4 percent chance (2- and 25-year), 24-hour storms. Design rainfall values for these events are tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992, pp. 126-129, and summarized for this site in Appendix A. These values have been multiplied by 0.93 to account for the size of the watershed.

These parameters were then incorporated into a HEC-HMS model to compute runoff volume and flow.

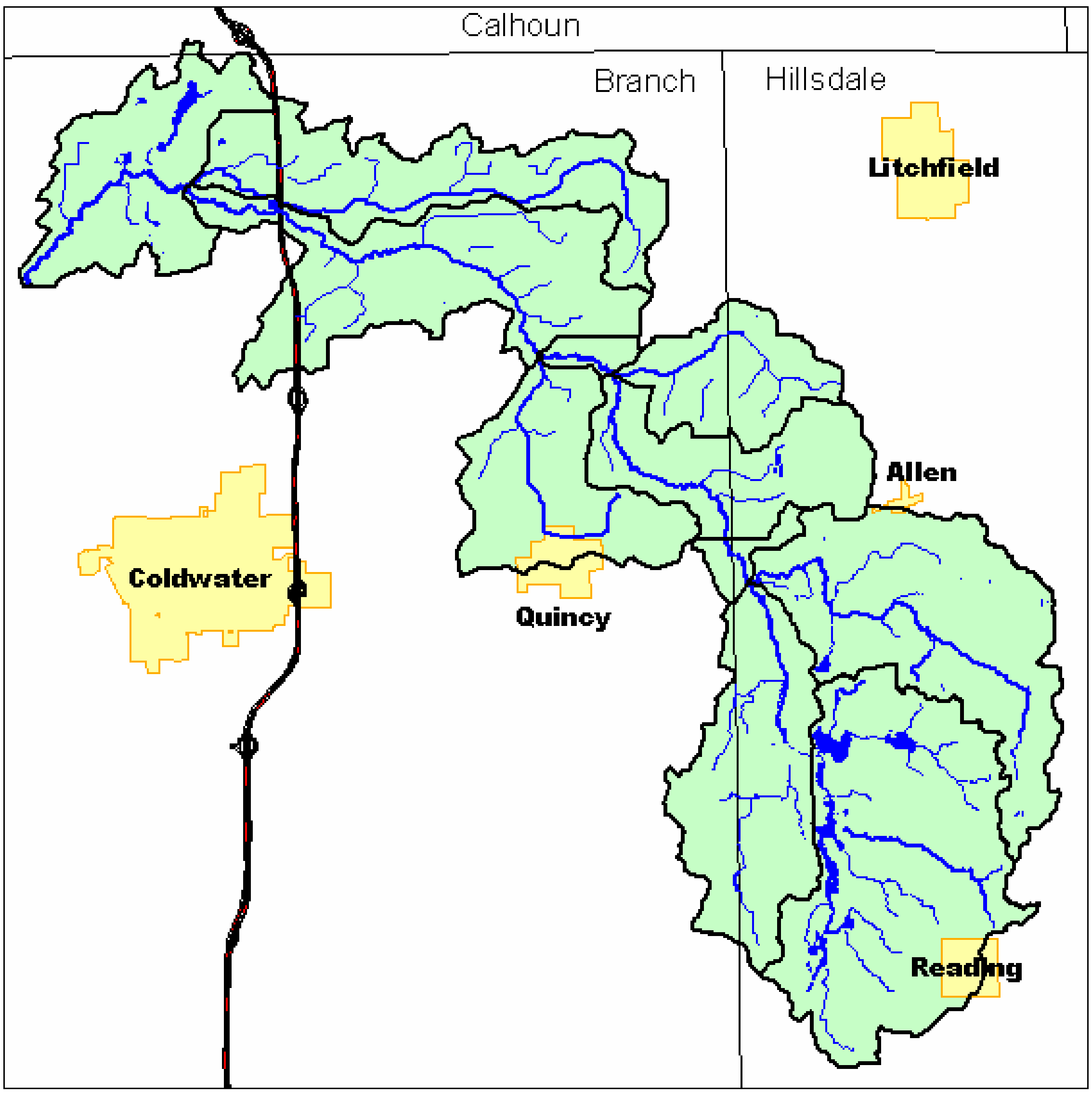

Figure 2: Delineated Hog Creek Watershed

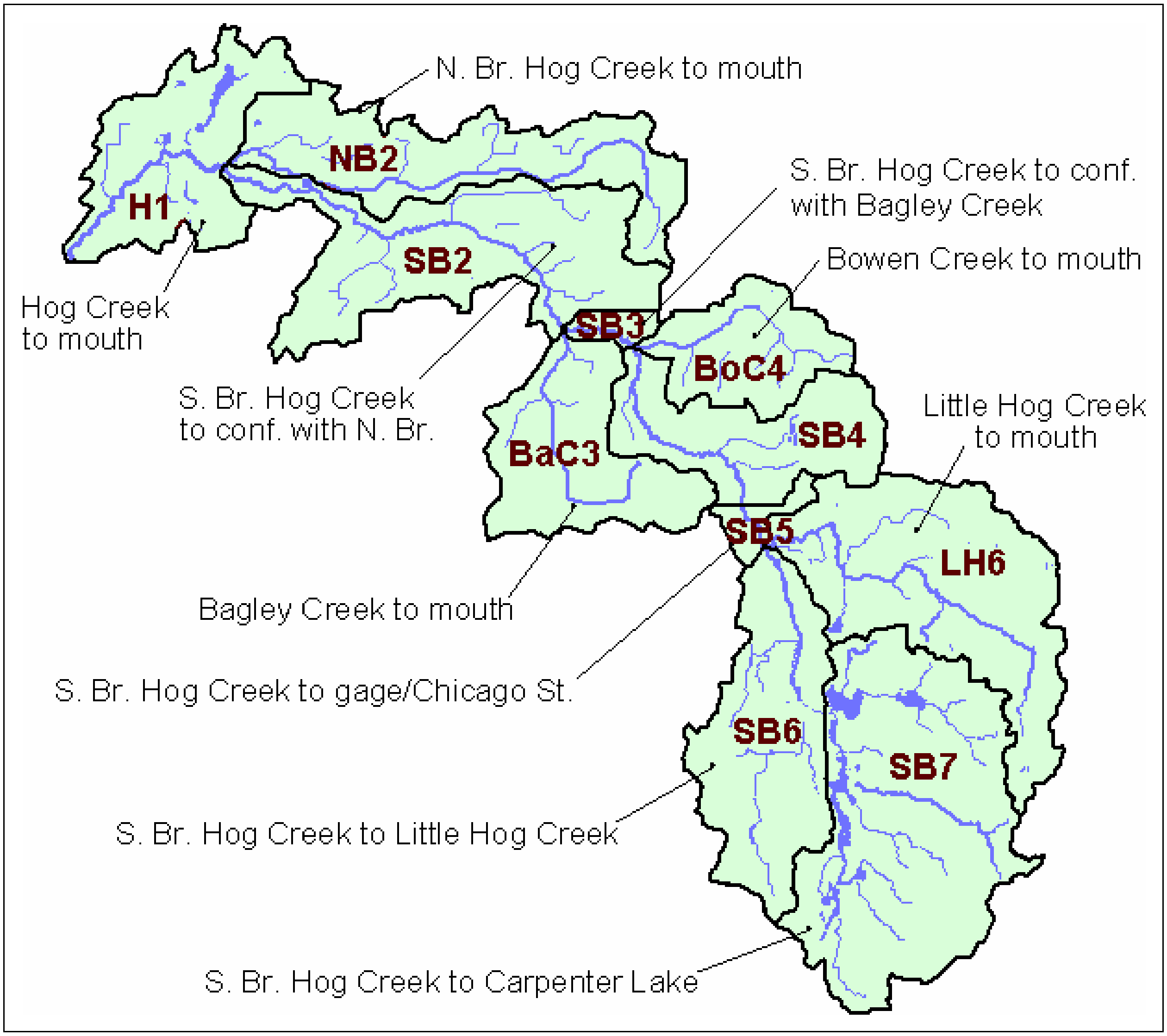

Figure 3: Subbasin Identification

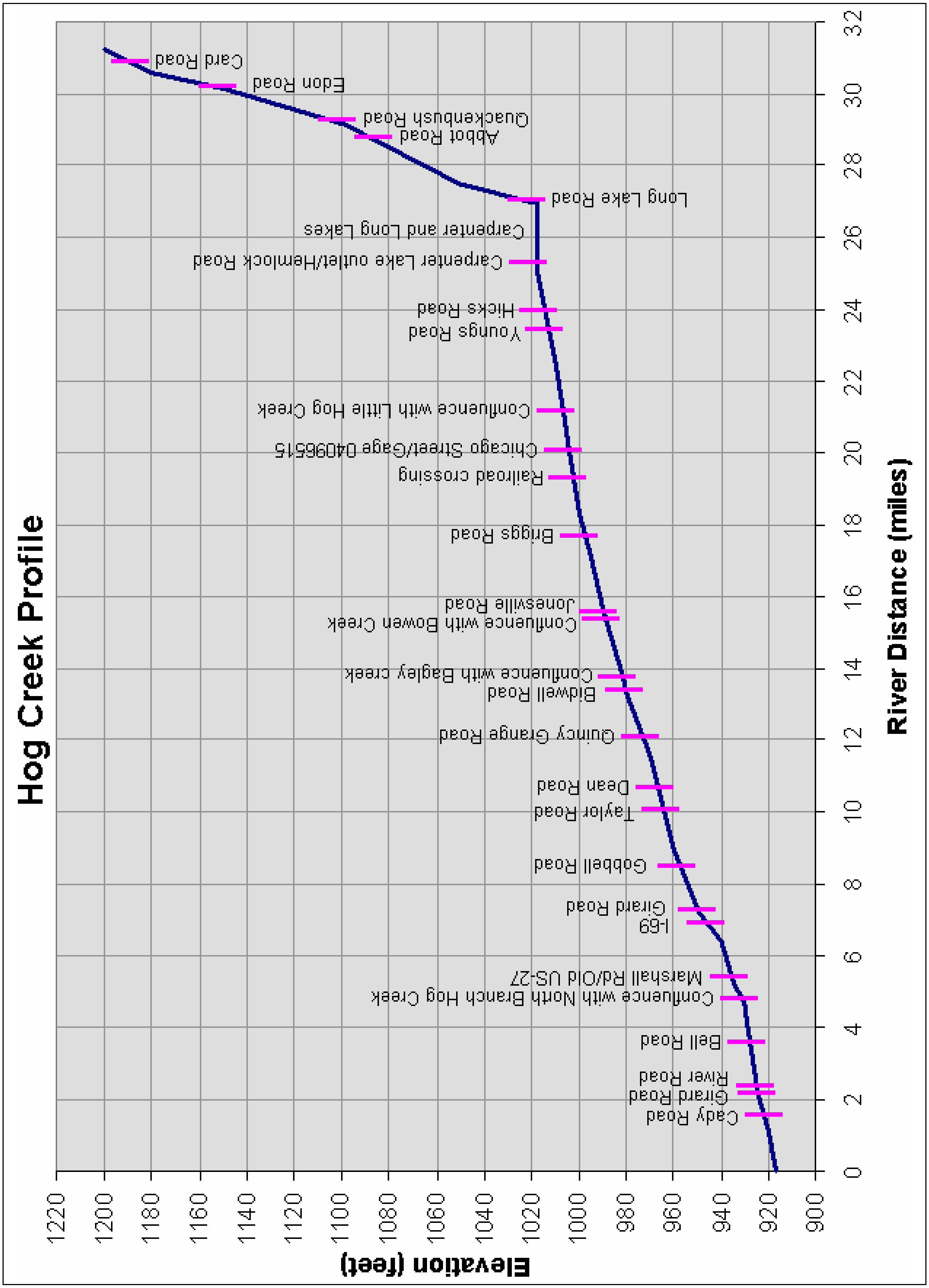

Figure 4: Hog Creek Profile

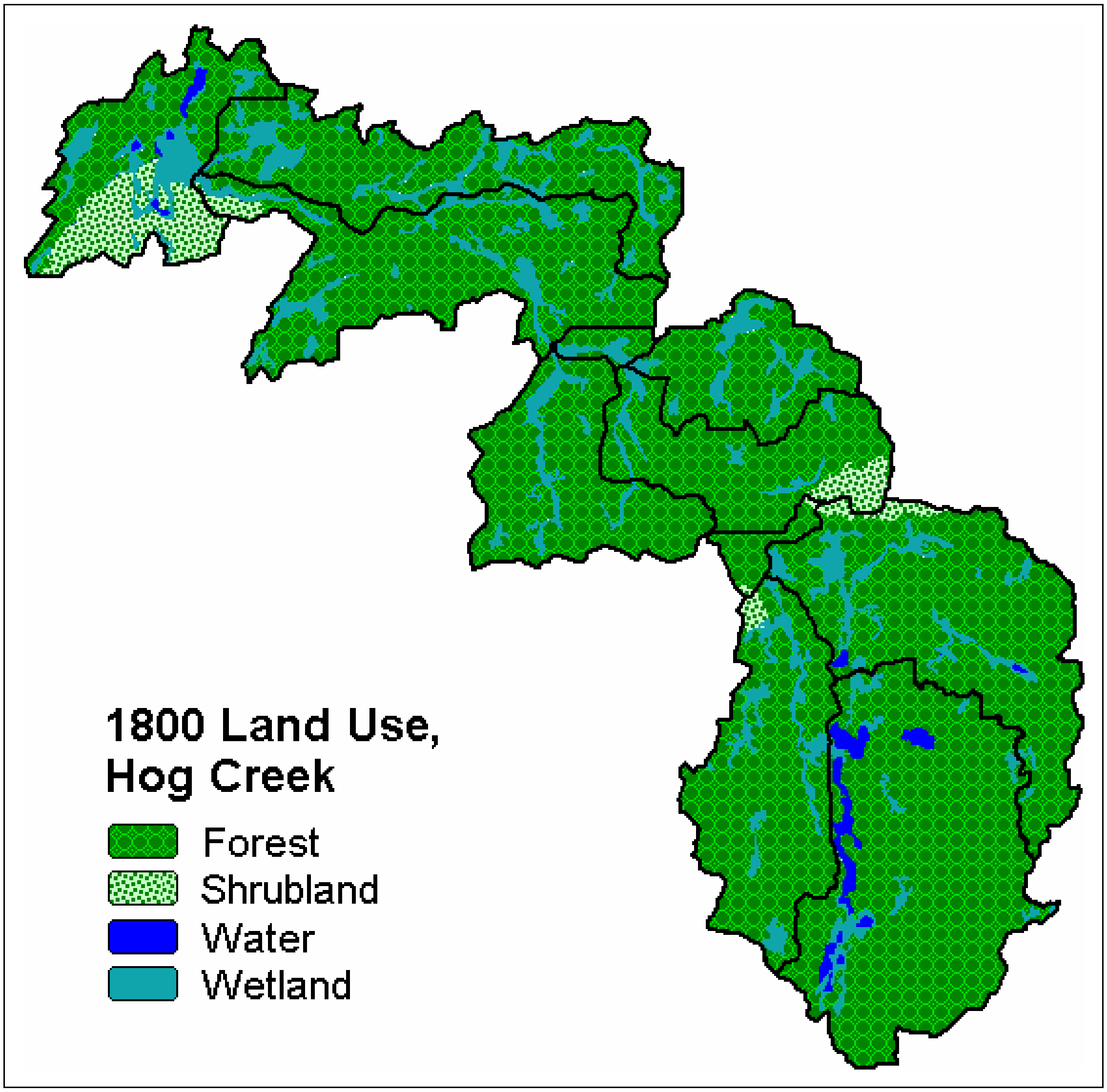

Figure 5: 1800 Land Use Data

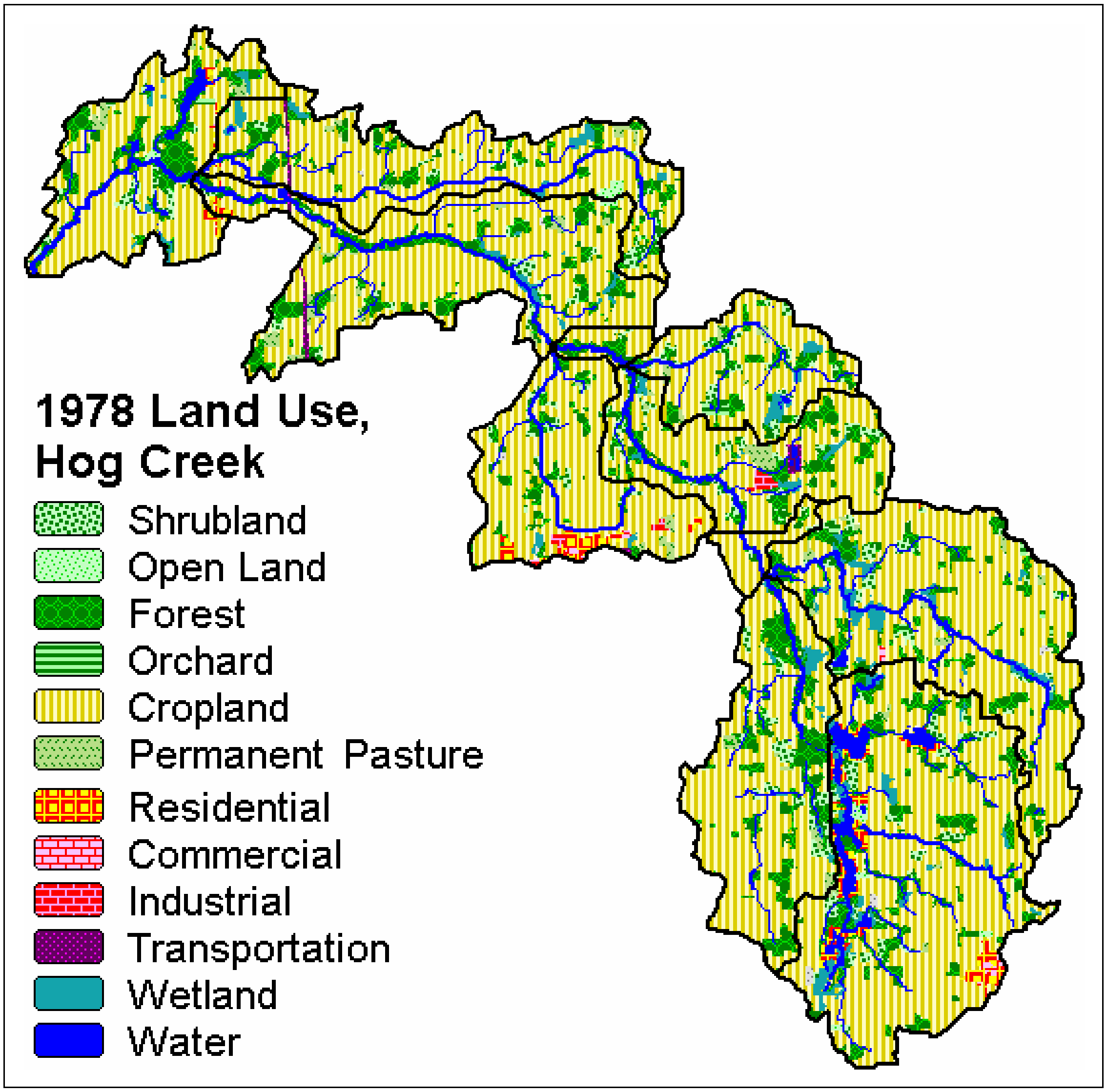

Figure 6: 1978 Land Use Data

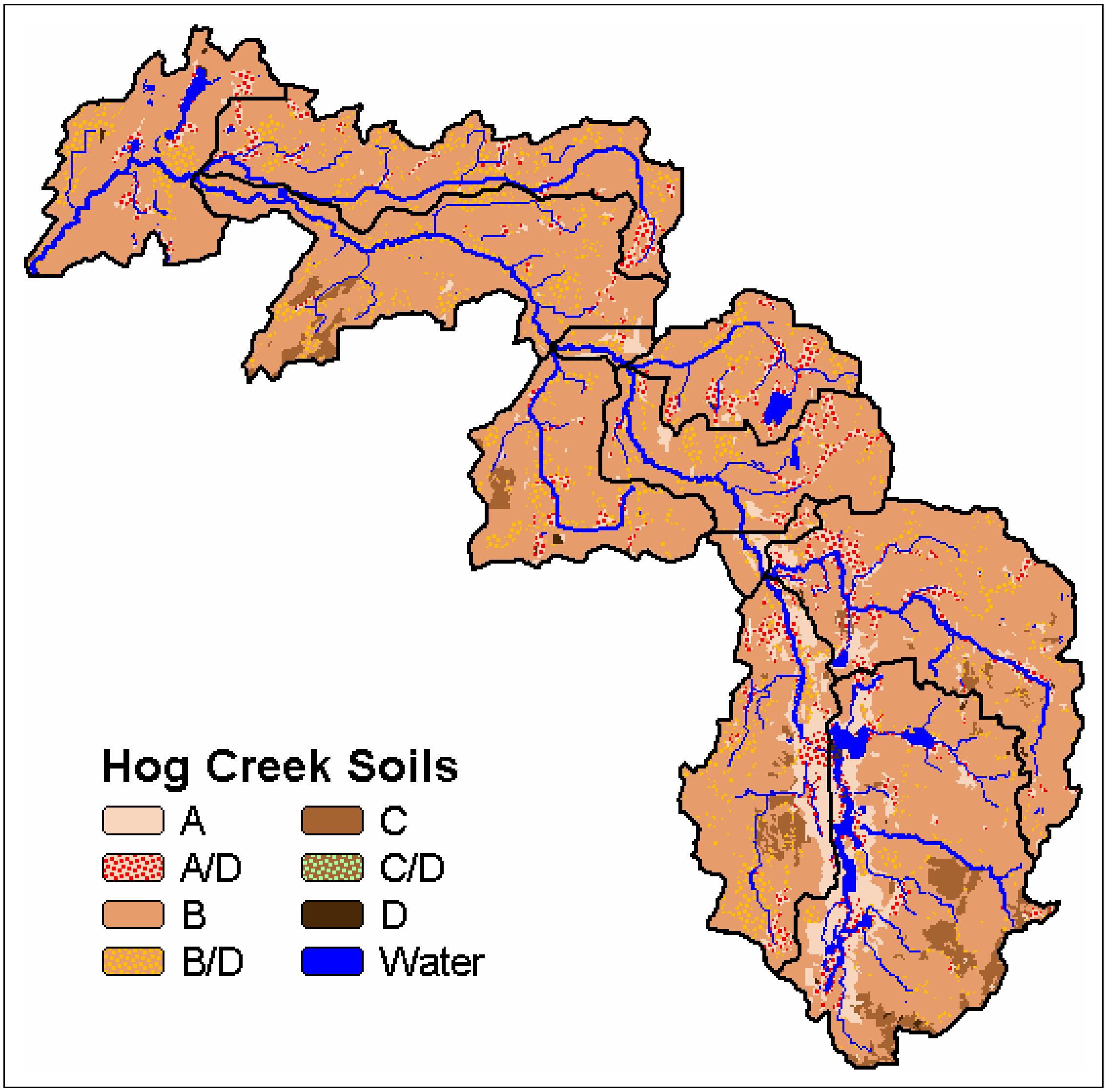

Figure 7: NRCS Soils Data

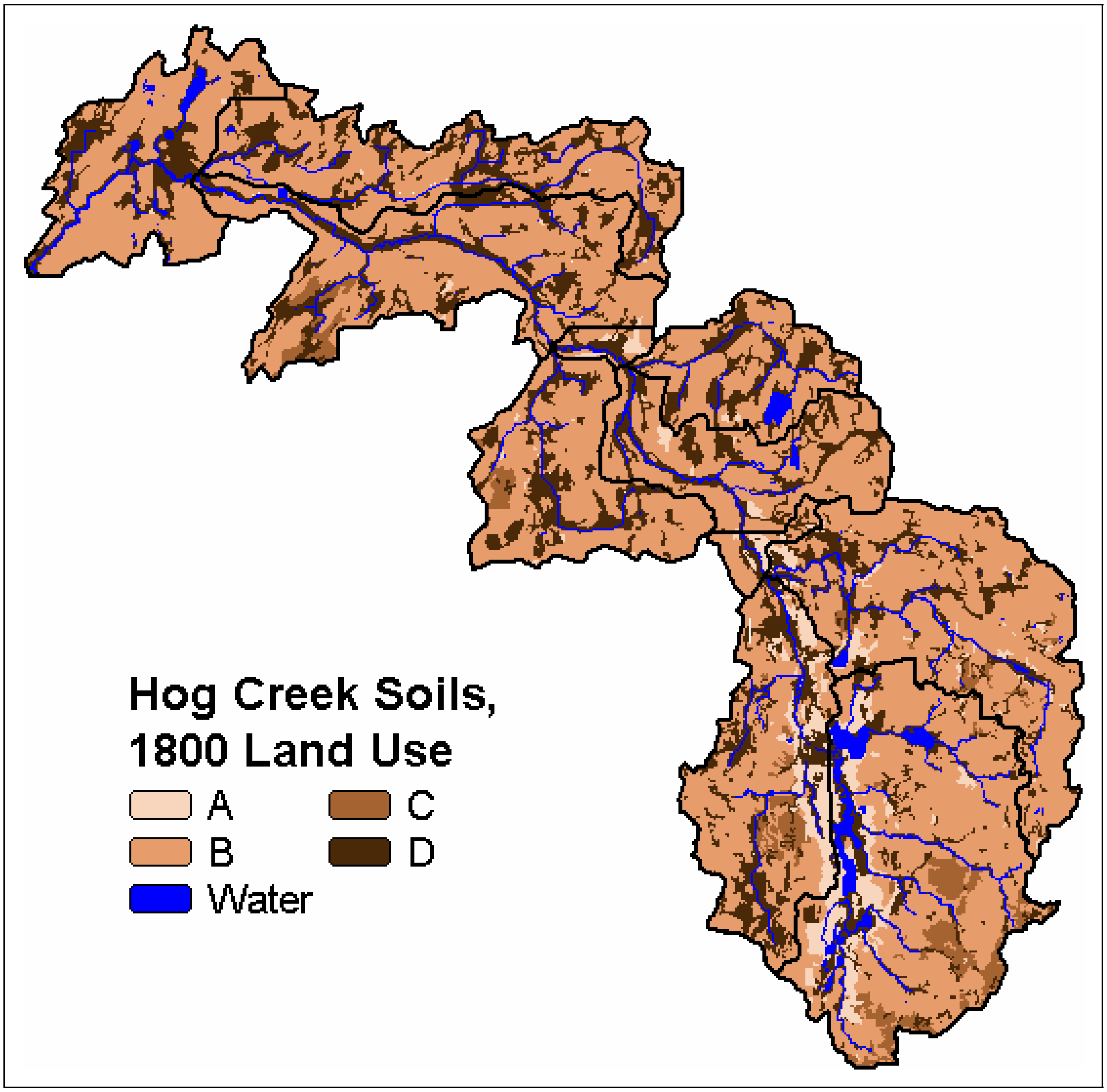

Figure 8: Resolved Soils, 1800 Land Use

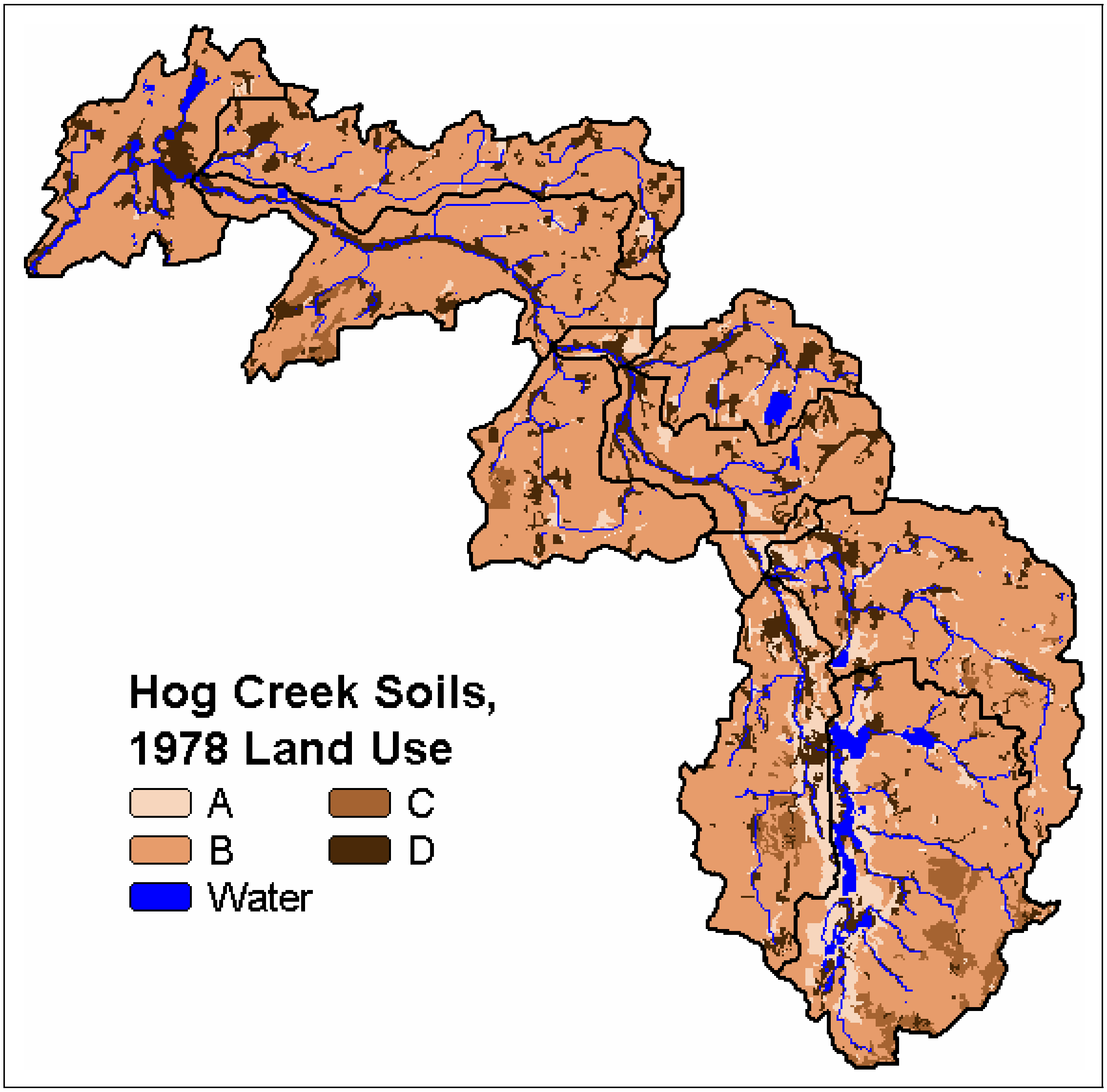

Figure 9: Resolved Soils, 1978 Land Use

Table 1: Land Use by Subbasins (Land uses less than 0.5 percent are not listed because all percentages are rounded to the nearest percent)

Description	Scenario	Residential	Institutional	Industrial	Utilities	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
H1	1800									31%	49%	2%	17%
	1978	1%					68%		2%	4%	20%	2%	2%
NB2	1800										82%		18%
	1978				1%	1%	76%		2%	3%	15%		3%
SB2	1800									2%	83%		14%
	1978				1%		73%		3%	3%	18%		2%
BaC3	1800										90%		10%
	1978	5%	1%	1%			78%		2%	3%	10%		1%
SB3	1800										70%		30%
	1978						61%			3%	36%		
BoC4	1800										83%		17%
	1978						68%	1%	2%	9%	15%		4%
SB4	1800									10%	83%		7%
	1978			1%	1%		66%		3%	7%	20%		2%
SB5	1800									7%	93%		
	1978						87%				5%	7%	1%
LH6	1800									3%	86%	1%	11%
	1978						75%	1%	2%	4%	13%		5%
SB6	1800									2%	85%		13%
	1978						70%		1%	5%	21%		2%
SB7	1800										90%	5%	5%
	1978	5%				1%	68%			4%	14%	4%	3%
Total	1800									5%	82%	1%	12%
	1978	1%					72%		2%	4%	16%	1%	3%

Model Results

General Results

Model results are illustrated in Figures 10 through 17 and detailed in Tables 2 and 3. Table 2 lists the computed peak flows and runoff volumes from each subbasin. These values represent the peak flow contribution from the subbasins, not the flow in the river. Table 3 and Figures 10 through 13 show the computed peak flows and runoff volumes at locations in the river.

The increases in stormwater runoff volume and peak flows conditions from 1800 to 1978 are due to changes in land use and loss of storage. The hydrologic model shows significant increases in runoff volumes and peak flows for both design storms. Peak flows and runoff volumes from the 50 percent chance, 24-hour storm are predicted to increase more, on a percentage basis, than flows from the 4 percent chance, 24-hour storm. Increases in runoff volumes and peak flows from the 50 percent chance storm increase channel-forming flows, which will increase streambank erosion as the stream enlarges to accommodate the higher flows. Channel-forming flow is the flow that is most effective at shaping the channel. In a stable stream, the channel-forming flow has a one- to two-year recurrence interval and is the bankfull flow. Increases in runoff volumes and peak flows from the 4 percent chance storm will aggravate flooding. These increases can be moderated through the use of effective stormwater management techniques. A stream can take 60 to 80 years or more to adapt to flow changes.

Yield Analysis

One way to compare runoff from subbasins or watersheds is to calculate the yield, which is the peak flow divided by the drainage area. Yields can be used as the basis for stormwater management BMPs. Kent County's model stormwater ordinance, www.accesskent.com/YourGovernment/DrainCommisioner/drain_stormwater.htm, calls for a maximum release rate of 0.05 cfs/acre for runoff from the 50 percent chance, 24-hour storm for environmentally sensitive zones. Currently, the area-weighted average yield from this storm for the Hog Creek Watershed is 0.02 cfs/acre, with no subbasin greater than 0.04 cfs/acre, as shown in Figure 14. The Kent County ordinance also calls for a maximum release rate of 0.13 cfs/acre for runoff from the 4 percent chance, 24-hour storm for most zones. Currently, the area-weighted average yield from this storm is 0.05 cfs/acre, with no subbasin greater than 0.15 cfs/acre, as shown in Figure 15. Additional details are listed in Table 2. If the Hog Creek watershed stakeholders use the Kent County model ordinance as a model for a Hog Creek stormwater ordinance, they should consider whether the Kent County model ordinance standards will adequately protect Hog Creek and its tributaries.

Some watershed plans have used yields as one criteria in selecting critical areas. In Hog Creek, the subbasins with above-average yields are SB3 (South Branch Hog Creek, to confluence with Bagley Creek), BaC3 (Bagley Creek, to mouth), BoC4 (Bowen Creek, to mouth), SB4 (South Branch Hog Creek, at Bowen Creek), and SB5 (South Branch Hog Creek, at Gage/Chicago Street).

Peak Flow Analysis

Figure 16 shows the 50 percent chance storm hydrograph for the South Branch of Hog Creek at its confluence with Bagley Creek. The contribution from each upstream subbasin is also shown. Based on this analysis, the subbasins that have the most effect on peak flow at this location are the same as the subbasins that have above average yields: SB3, BaC3, BoC4, SB4, and SB5.

Figure 17 illustrates that peak flows downstream of the confluence of the north and south branches of Hog Creek are controlled by flows from the south branch. The peak flow from the north branch precedes the peak flow from the south branch in this analysis by approximately 12 hours.

Flashiness Analysis

Flashiness has no set definition but is associated with the rate of change of flow. Flashy streams have more rapid flow changes. There have been several attempts to classify stream flashiness. For this analysis, we used the methodology detailed in "A New Flashiness Index: Characteristics and Applications to Midwestern Rivers and Streams, published in the Journal of the American Water Resources Association, April 2004, by David Baker, et al. The Richards-Baker Flashiness Index is based on mean daily flows. Mean daily flows, Figure 18, are available for the south branch of Hog Creek at USGS gage 04096515, which is located on the downstream side of Chicago Road. The flashiness index was calculated for each year and shown in Figure 19. The calculated flashiness index values are near the less flashy end of the of range calculated by Baker et al., Figure 20. Regression analysis was performed on the index values using Microsoft Excel's Analysis ToolPak Add-in. The resulting trendline, shown in Figure 19, shows an upward trend in the flashiness index that is statistically significant ($p=0.0003$). This suggests that there are hydrologic changes in the watershed above the gage that are causing the south branch of Hog creek to become relatively more flashy, which could cause streambank erosion as the affected stream(s) adapt to the higher flows.

The Hog Creek watershed group has expressed concern about erosion in the streams that are tributary to the chain of lakes in the head waters of the south branch of Hog Creek. The streams, shown in Figure 21, exhibit comparatively high water velocities, extensive streambank erosion, and possible stream bed downcuts. The streams were carrying visibly high sediment loads at the higher flows observed on February 14, 2005, Figures 22 through 25. The sediment was likely derived from streambank erosion; runoff from agricultural fields, which are typically bare soil at this time of year; and runoff from gravel roads, which are common in this part of the watershed. This study does not assess streams at this scale because it does not delineate separate subbasins for each of these tributaries. It is, however, evident that the streams are contributing a significant amount of sediment to the chain of lakes. Hydrologic changes in the upper watershed that impact these headwater streams could be a factor in the gage's flashiness index upward trend.

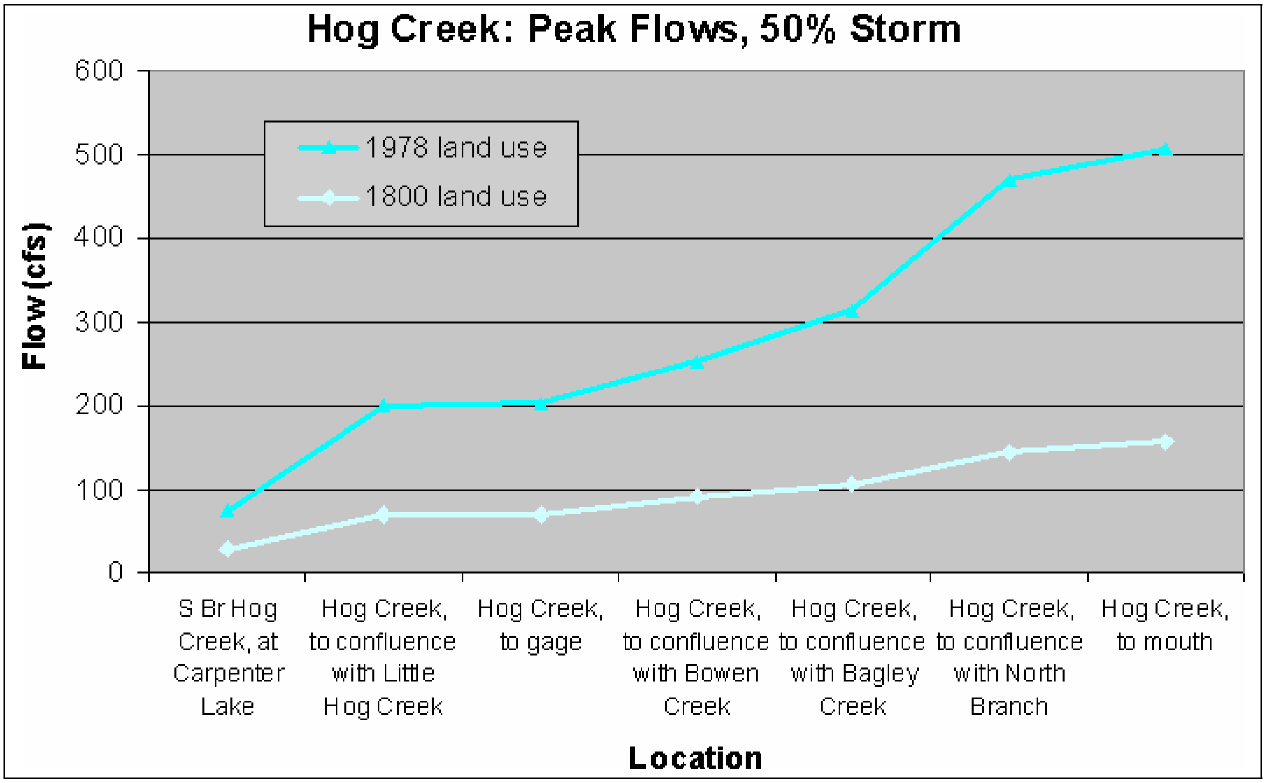

Figure 10: Predicted peak flows for river locations, 50 percent chance storm

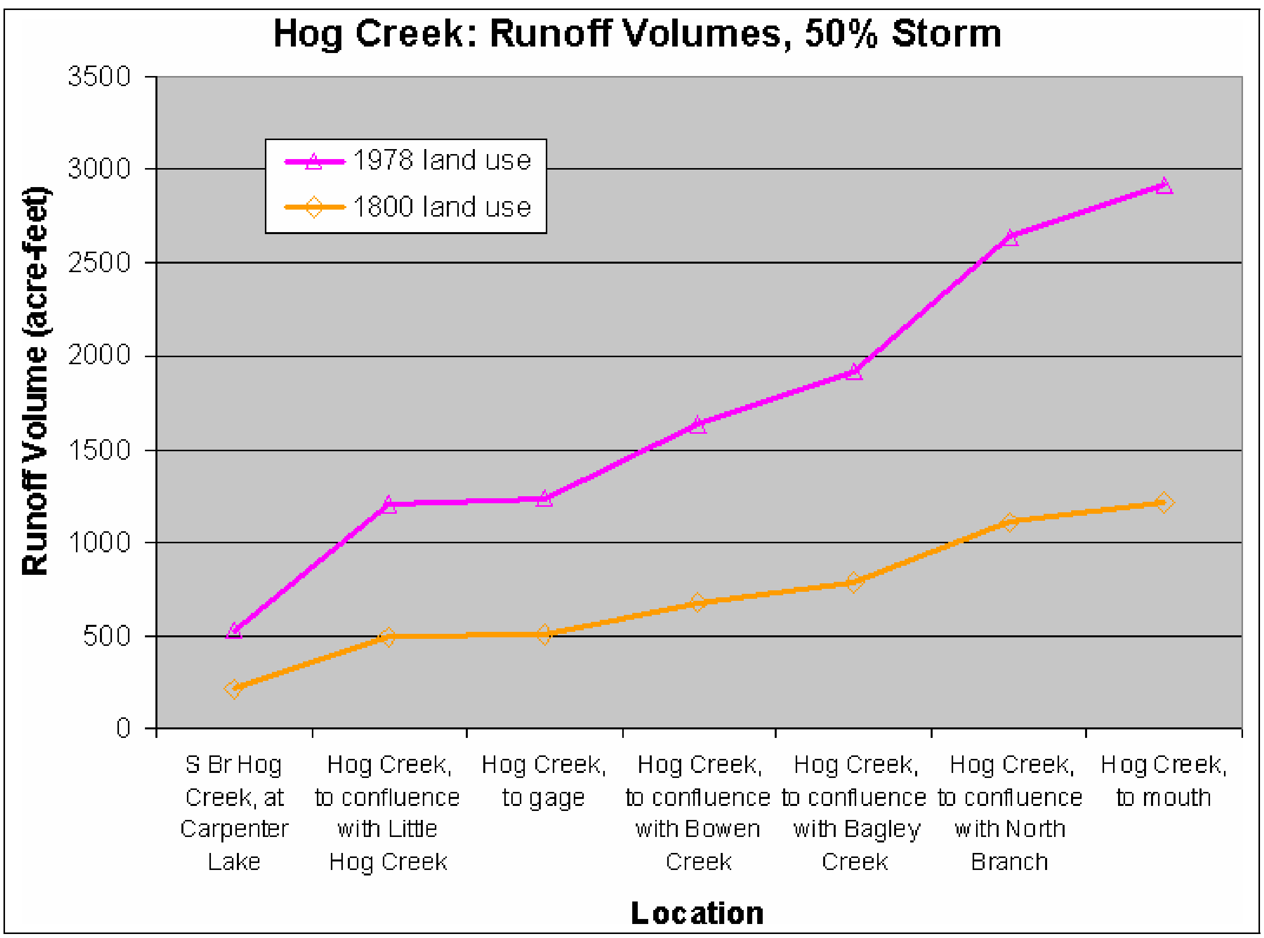

Figure 11: Predicted runoff volumes, 50 percent chance storm

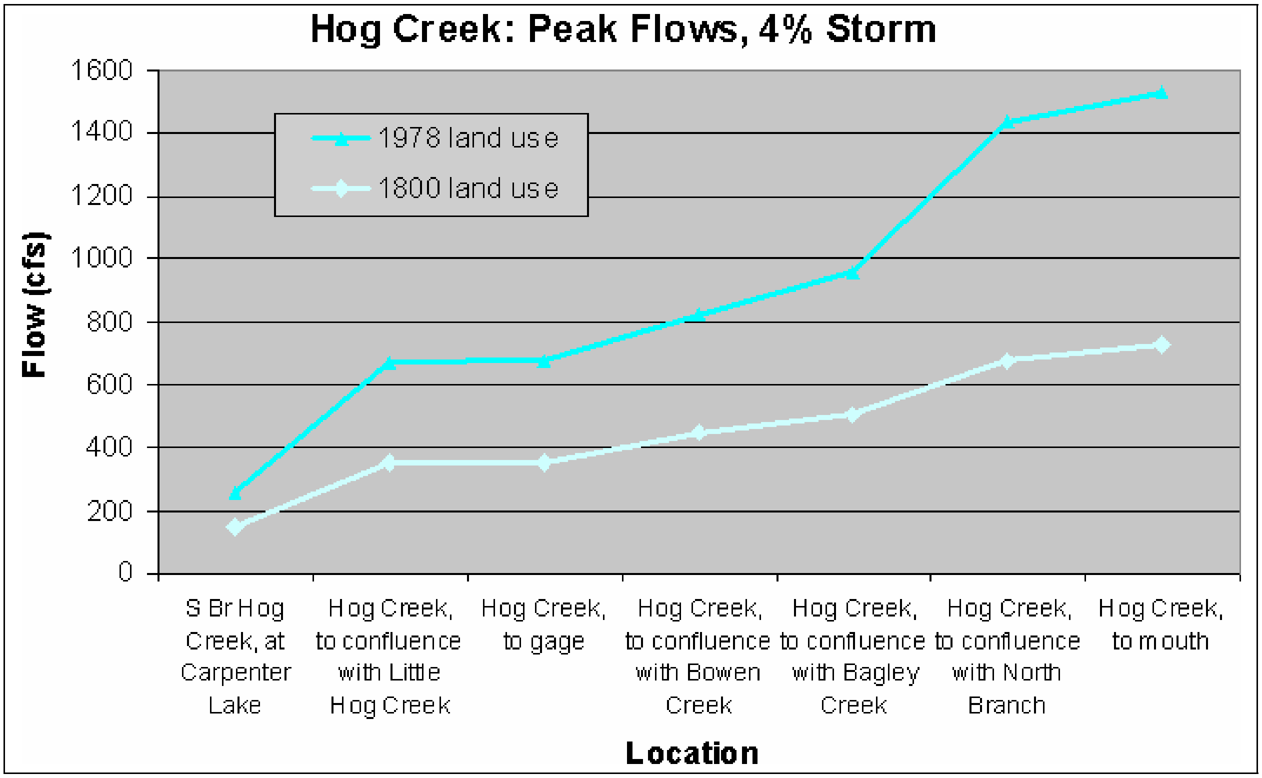

Figure 12: Predicted peak flows for river locations, 4 percent chance storm

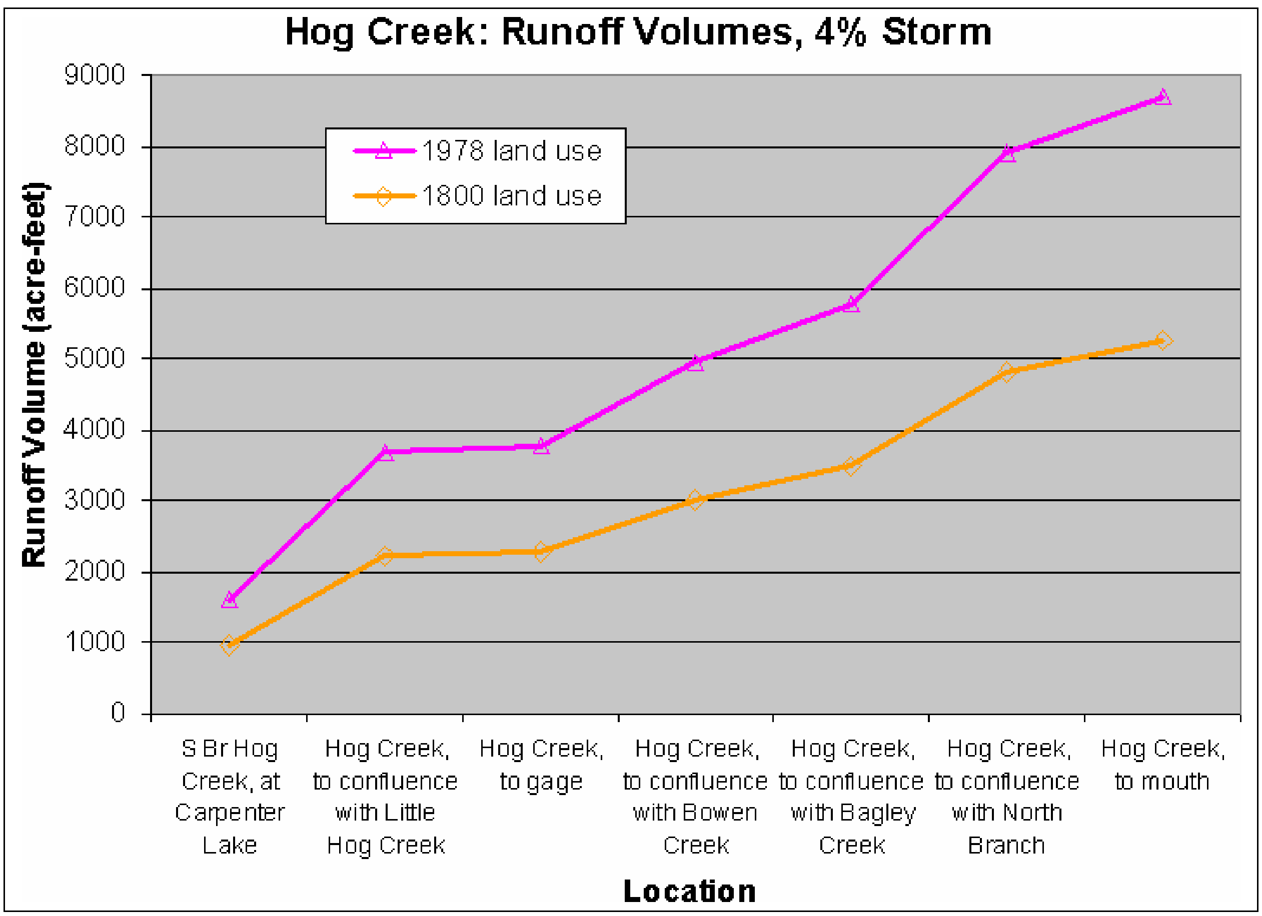

Figure 13: Predicted runoff volumes, 4 percent chance storm

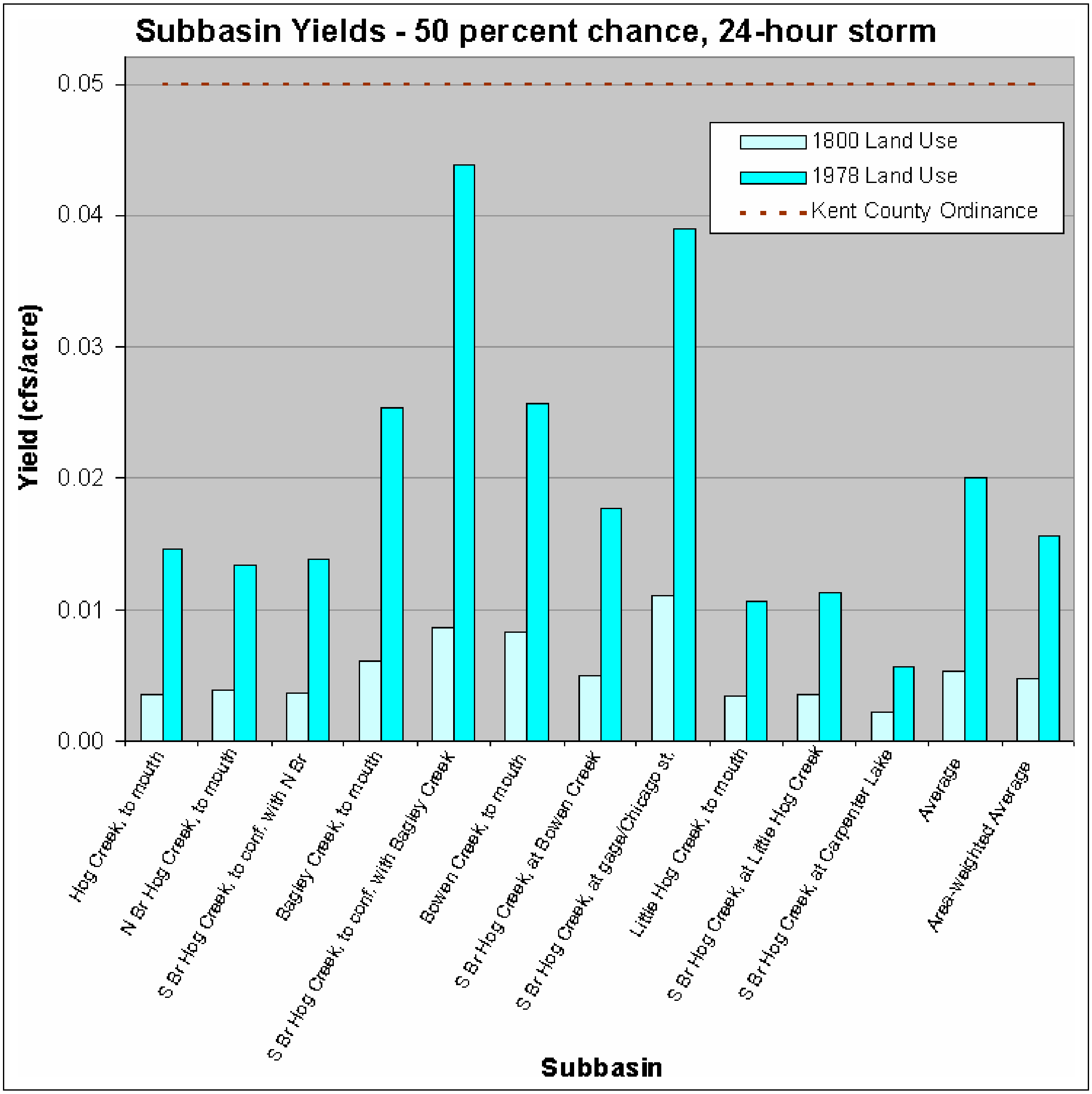

Figure 14: Subbasin Yields, 50 percent chance, 24-hour storm

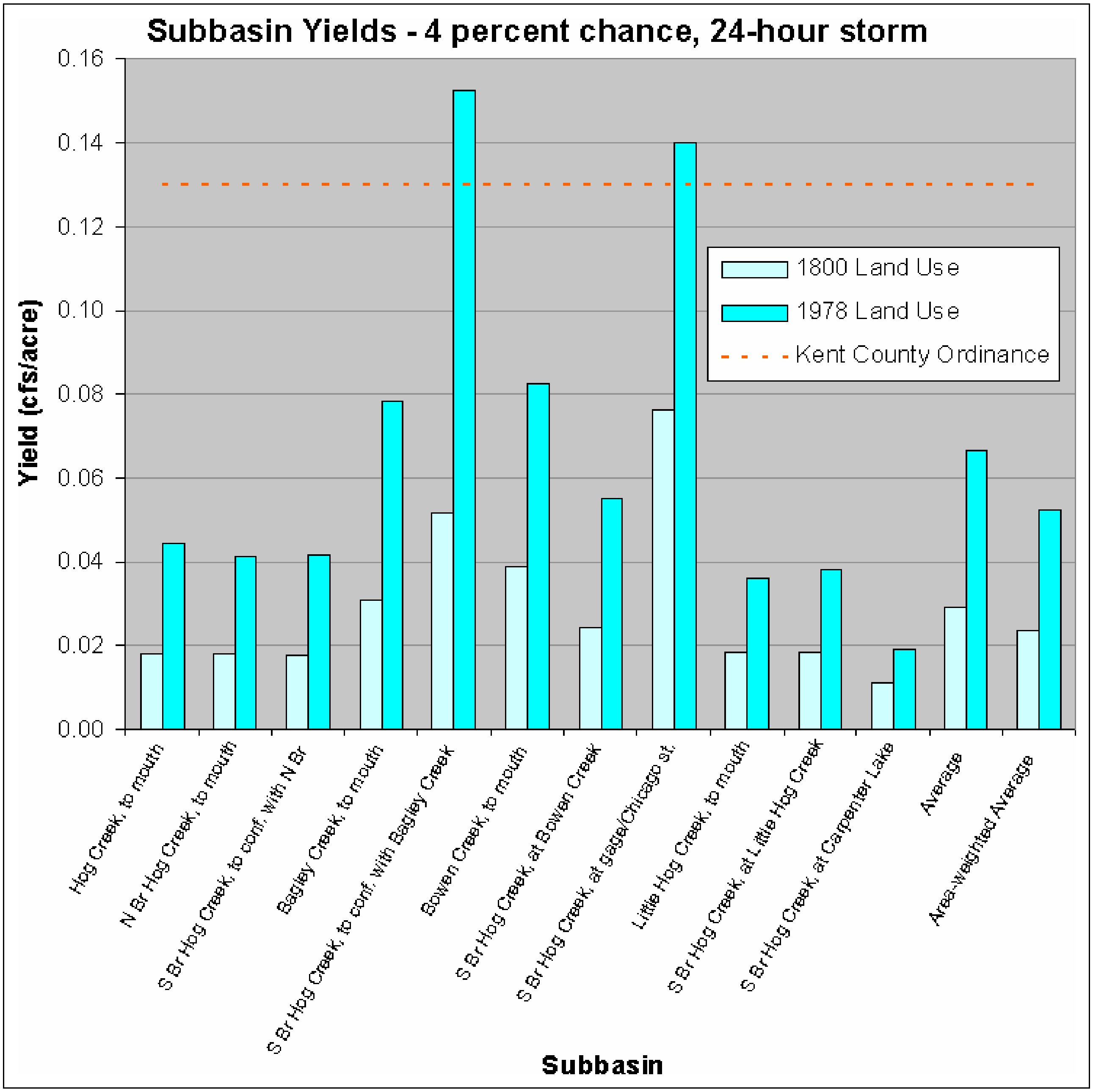

Figure 15: Subbasin Yields, 4 percent chance, 24-hour storm

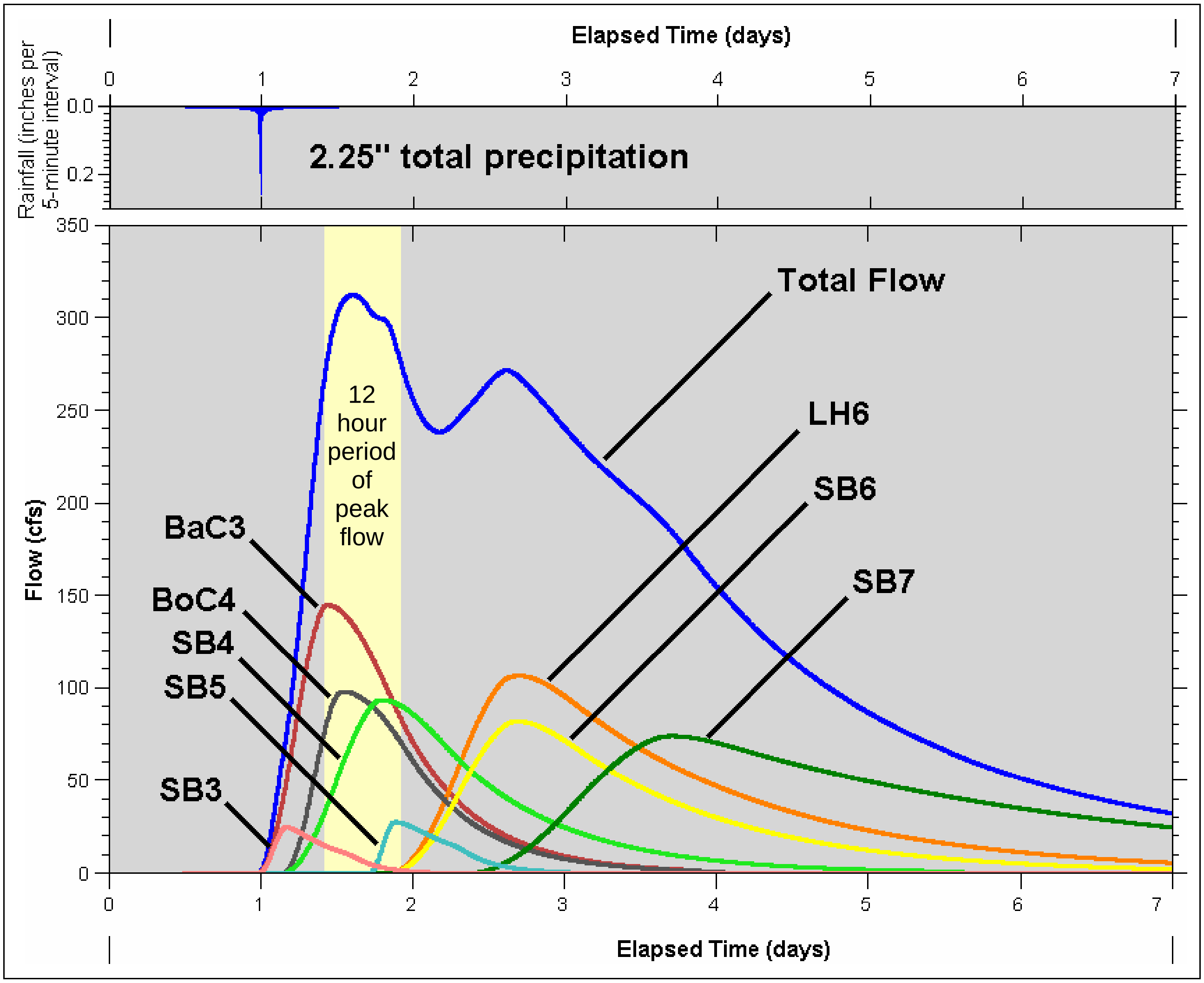

Figure 16: 50 percent chance, 24-hour storm partial hydrograph for Hog Creek at confluence of South Branch with Bagley Creek

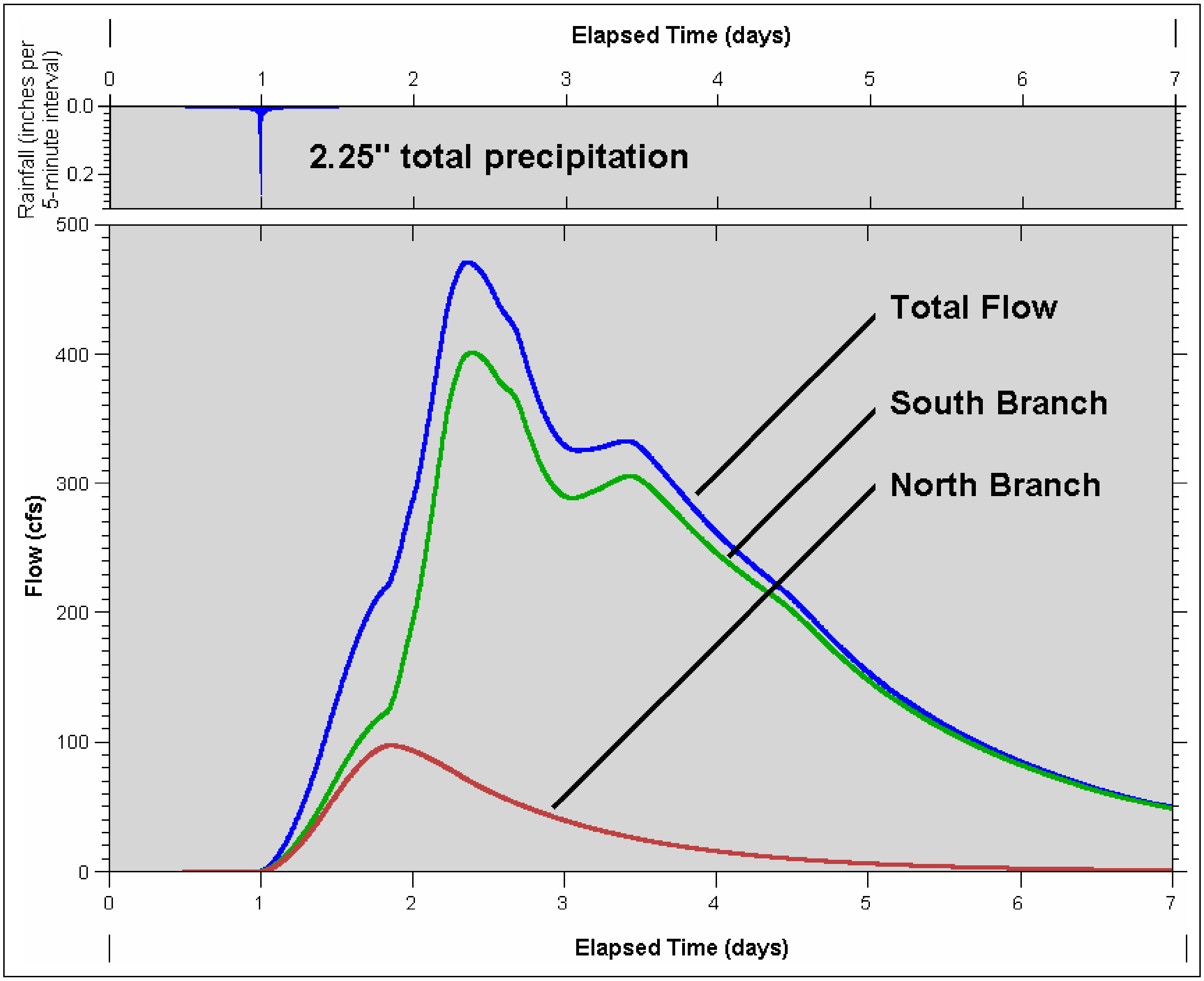

Figure 17: 50 percent chance, 24-hour storm partial hydrograph for Hog Creek at the confluence of the north and south branches

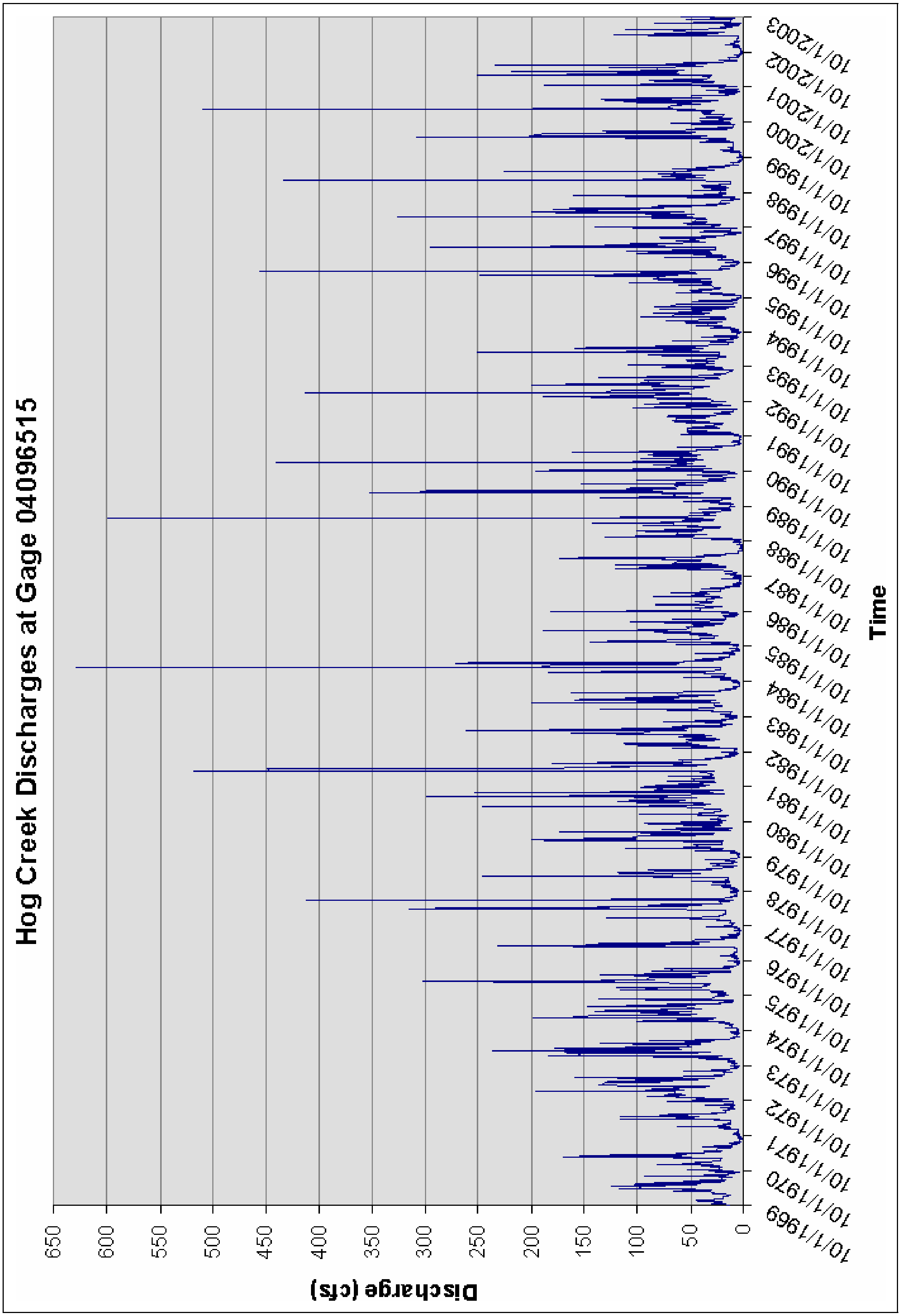

Figure 18: Daily Discharges for Hog Creek at USGS Gage 04096515

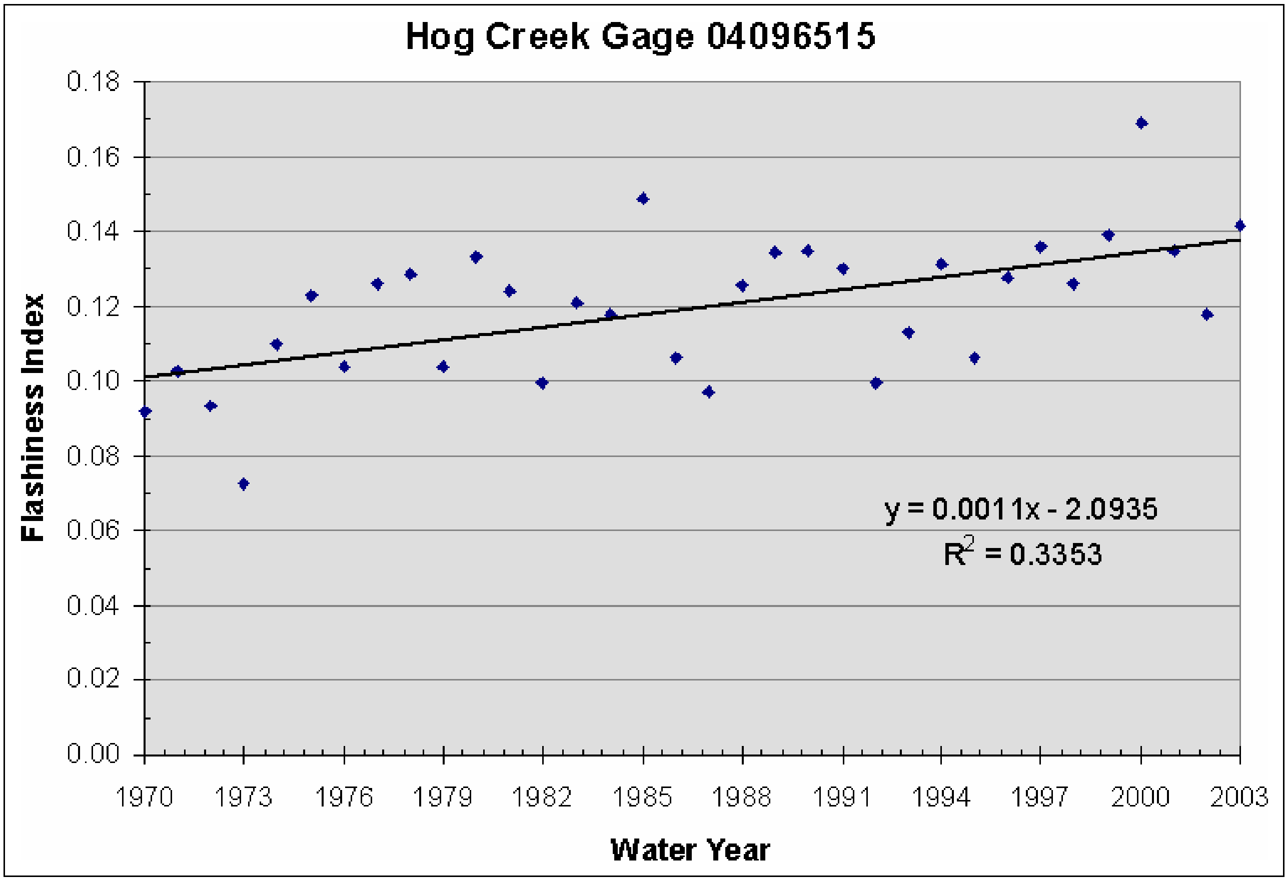

Figure 19: Richards-Baker Flashiness Index Analysis for Hog Creek at Gage 04096515

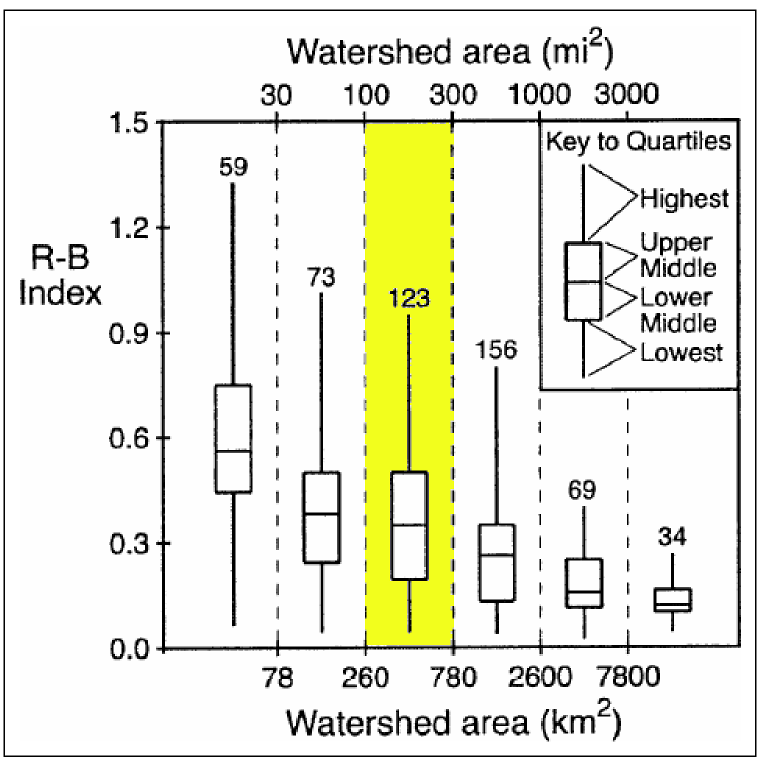

Figure 20: Distribution of Richards-Baker Index Values for Streams in Six Watershed Size Classes (Hog Creek Class highlighted), Showing Quartiles of Index Values. The whiskers of the box plots extend to the maximum or minimum values.

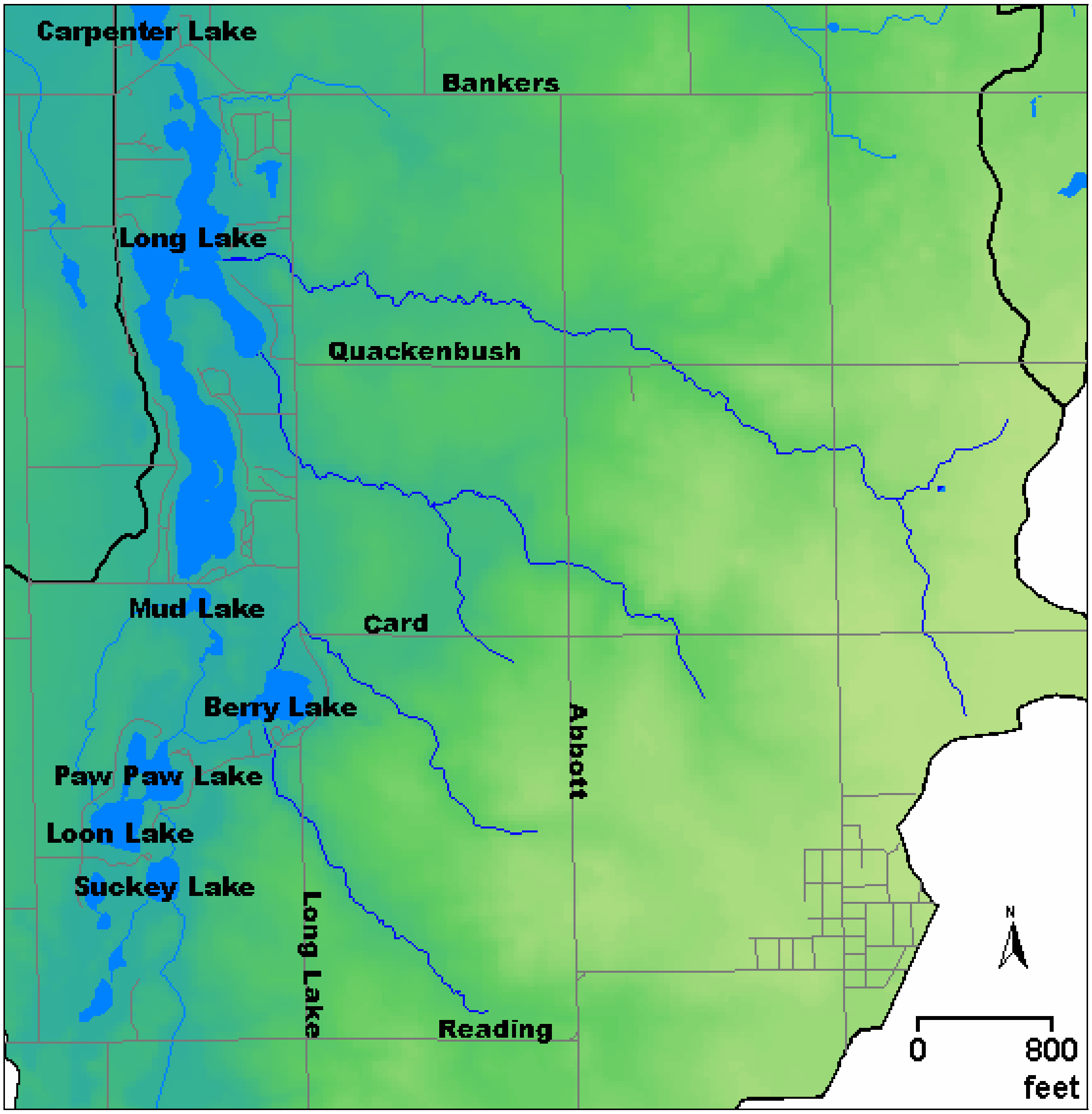

Figure 21: Tributaries to the chain of lakes


Figure 22: Tributary to Long Lake, at Long Lake Road, south of Quakenbush Road


Figure 23:Tributary to Long Lake at Abbot Road, south of Quakenbush Road


Figure 24: Tributary to Long Lake, at Long Lake Road, north of Quakenbush Road

Figure 25: Tributary to Berry Lake at Card Road, east of Long Lake Road

Table 2: Peak flows and runoff volumes per subbasin

Subbasin			Land Use	Peak Flow (cfs)		Yield (cfs/acre)		Runoff Volume (acre-feet)	
ID	Description	Area (sq. mi.)		50%	4%	50%	4%	50%	4%
H1	Hog Creek, to mouth	9.5	1800	22	109	0.004	0.018	110	472
			1978	88	269	0.015	0.044	284	815
NB2	North Branch Hog Creek, to mouth	11.3	1800	28	131	0.004	0.018	146	596
			1978	97	299	0.013	0.041	320	939
SB2	South Branch Hog Creek, to confluence with North Branch	14.2	1800	33	158	0.004	0.017	175	729
			1978	125	378	0.014	0.042	412	1196
BaC3	Bagley Creek, to mouth	8.9	1800	35	177	0.006	0.031	104	445
			1978	145	448	0.025	0.079	259	752
SB3	South Branch Hog Creek, to confluence with Bagley Creek	0.9	1800	5	29	0.009	0.052	10	43
			1978	25	86	0.044	0.152	22	67
BoC4	Bowen Creek, to mouth	6.0	1800	31	147	0.008	0.039	86	334
			1978	98	314	0.026	0.082	172	500
SB4	South Branch Hog Creek, at Bowen Creek	8.2	1800	26	129	0.005	0.025	92	399
			1978	93	289	0.018	0.055	231	678
SB5	South Branch Hog Creek, at gage/Chicago Street	1.1	1800	8	54	0.011	0.076	8	44
			1978	27	99	0.039	0.140	28	86
LH6	Little Hog Creek, to mouth	15.7	1800	35	184	0.004	0.018	157	721
			1978	106	360	0.011	0.036	414	1246
SB6	South Branch Hog Creek, at Little Hog Creek	11.4	1800	26	133	0.004	0.018	122	542
			1978	82	276	0.011	0.038	274	856
SB7	South Branch Hog Creek, at Carpenter Lake	20.5	1800	29	146	0.002	0.011	216	969
			1978	74	253	0.006	0.019	522	1600
	Average		1800			0.005	0.029		
			1978			0.020	0.066		
	Area-weighted Average		1800			0.005	0.024		
			1978			0.016	0.052		

Table 3: Peak flows and runoff volumes in Hog Creek

River Location		Land Use	Peak Flow (cfs)		Yield (cfs/acre)		Runoff Volume (acre-feet)	
Description	Drainage Area (sq. mi.)		50 %	4%	50%	4%	50%	4%
Hog Creek, at mouth	108	1800	156	730	0.002	0.011	1214	5263
		1978	506	1531	0.007	0.022	2917	8691
South Branch Hog Creek, at confluence with North Branch	98	1800	144	674	0.002	0.011	1108	4800
		1978	471	1433	0.008	0.023	2639	7890
South Branch Hog Creek, at confluence with Bagley Creek	73	1800	107	503	0.002	0.011	791	3486
		1978	312	954	0.007	0.021	1914	5769
South Branch Hog Creek, at confluence with Bowen Creek	63	1800	93	447	0.002	0.011	677	2999
		1978	252	820	0.006	0.020	1634	4953
South Branch Hog Creek, at gage/Chicago Street	49	1800	70	350	0.002	0.011	501	2270
		1978	203	674	0.007	0.022	1235	3782
South Branch Hog Creek, at confluence with Little Hog Creek	47	1800	70	350	0.002	0.012	493	2228
		1978	201	670	0.007	0.022	1208	3698
South Branch Hog Creek, at Carpenter Lake	20	1800	29	146	0.002	0.011	216	969
		1978	74	253	0.006	0.019	522	1600

Appendix: Hog Creek Hydrologic Model Parameters

This appendix is provided so that the model may be recreated. Table A1 provides the design rainfall values specific to the region of the state where the Hog Creek is located. Figure A1 summarizes the hydrologic elements in the HEC-HMS model. Tables A2 and A3 provide the parameters that were specified for each of these hydrologic elements. The percent impervious field is left at 0.0, because it is already incorporated in the curve numbers. The initial loss field is left blank so that HEC-HMS uses the default equation based on the curve number. The ponding adjustment factors that were used to adjust the storage coefficients, which represent storage in the subbasin, to provide a peak flow reduction equal to the ponding adjustment factors, are listed in Table A4. Table A5 provides the reach parameters for the lag routing method. HEC-HMS was run for a 12-day duration using a 5-minute computation interval.

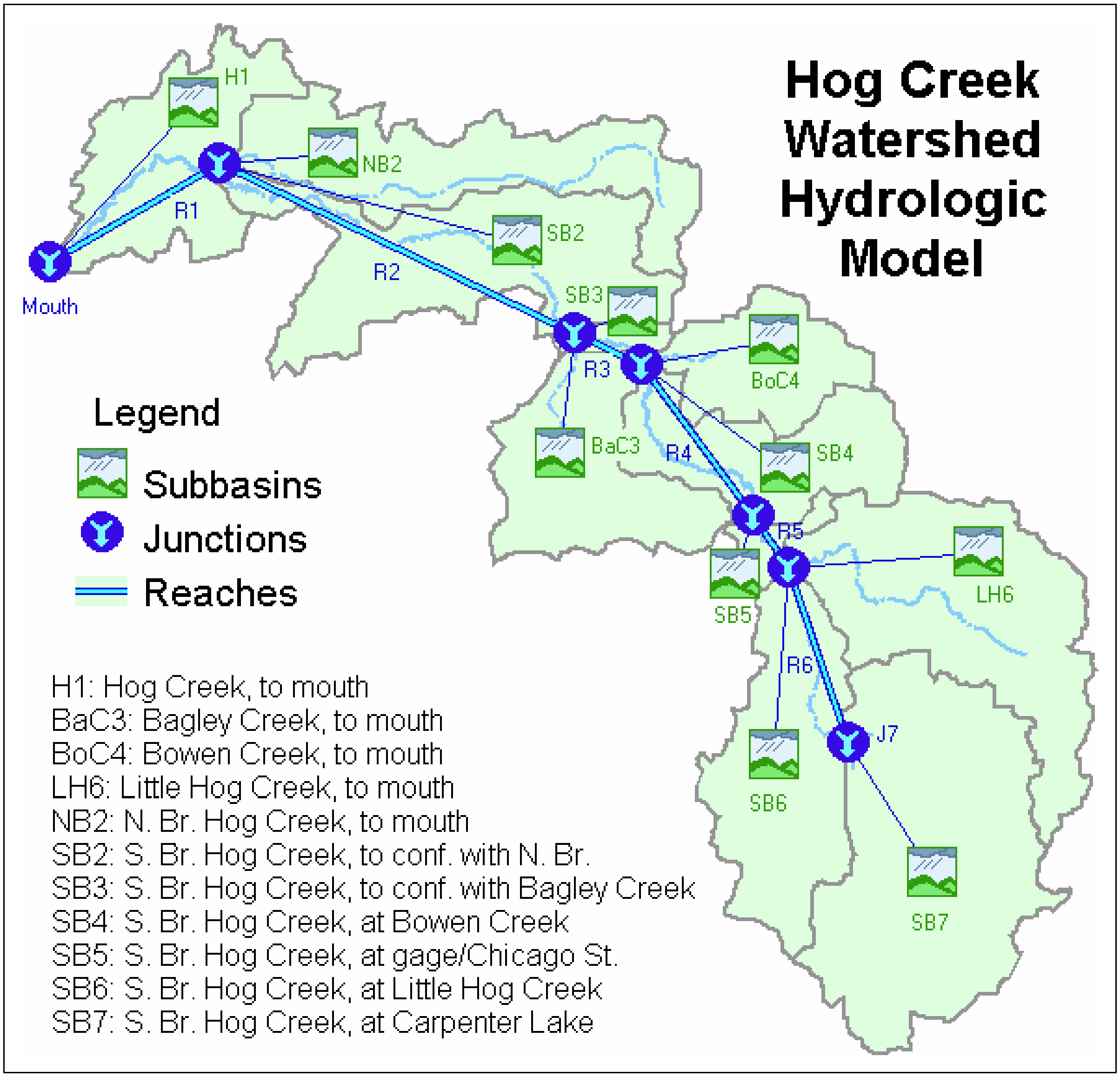

Figure A1: Hydrologic Elements defined for HEC-HMS model

Table A1: Design Rainfall Values

SCS Type II Precipitation Event	Precipitation	Area-adjusted Precipitation*
50% chance (2-year), 24-hour storm	2.42 inches	2.25 inches
4% chance (25-year), 24-hour storm	4.09 inches	3.80 inches

*standard values were multiplied by 0.93 to account for the watershed size

Table A2: Subbasin Parameters – Area and Curve Number

Subbasins		Drainage Area (sq. mi.)	Runoff Curve Number	
ID	Description		1800	1978
H1	Hog Creek, to mouth	9.5	65.3	76.3
BaC3	Bagley Creek, to mouth	8.9	65.4	75.9
BoC4	Bowen Creek, to mouth	6.0	67.5	75.8
LH6	Little Hog Creek, to mouth	15.7	64.0	74.6
NB2	N Br Hog Creek, to mouth	11.3	66.3	75.5
SB2	S Br Hog Creek, to conf. with N Br	14.2	65.9	75.9
SB3	S Br Hog Creek, to conf. with Bagley Creek	0.9	65.1	73.7
SB4	S Br Hog Creek, at Bowen Creek	8.2	65.0	75.5
SB5	S Br Hog Creek, at gage/Chicago st.	1.1	61.6	74.1
SB6	S Br Hog Creek, at Little Hog Creek	11.4	64.6	73.4
SB7	S Br Hog Creek, at Carpenter Lake	20.5	64.7	74.4

Table A3: Subbasin Parameters – Times of Concentration and Storage Coefficients

Subbasin ID	Land Use Scenario	Time of Concentration (hours)	Storage Coefficient	
			50% chance, 24-hour storm	4% chance, 24-hour storm
H1	1800	18.82	46.18	38.72
	1978		25.68	23.99
BaC3	1800	10.21	24.56	19.53
	1978		11.69	11.23
BoC4	1800	8.35	22.27	17.05
	1978		11.57	10.73
LH6	1800	18.04	40.18	33.91
	1978		33.55	29.14
NB2	1800	20.22	47.96	40.52
	1978		26.04	24.72
SB2	1800	21.26	48.20	40.98
	1978		25.91	24.66
SB3	1800	4.07	14.33	9.34
	1978		4.07	4.07
SB4	1800	14.60	30.34	25.48
	1978		18.35	17.43
SB5	1800	3.57	3.57	3.57
	1978		5.26	4.90
SB6	1800	18.72	42.27	35.71
	1978		27.11	24.81
SB7	1800	30.37	73.08	62.39
	1978		68.12	58.71

Table A4: Ponding Adjustment Factors

1800 Ponding Adjustment				
Subbasin	Percent Ponding within Subbasin	Location of Ponding within Subbasin	50% Storm Adjustment Factor	4% Storm Adjustment Factor
H1	19.9%	Throughout/middle	0.53	0.60
BaC3	10.2%	Throughout/middle	0.58	0.65
BoC4	16.8%	Throughout/middle	0.55	0.62
LH6	11.1%	Throughout/middle	0.57	0.64
NB2	17.7%	Throughout/middle	0.54	0.61
SB2	14.1%	Throughout/middle	0.56	0.63
SB3	30.2%	Throughout/middle	0.49	0.57
SB4	7.1%	Throughout/middle	0.62	0.69
SB5	0.0%		1.00	1.00
SB6	12.7%	Throughout/middle	0.57	0.64
SB7	10.4%	Lower	0.53	0.60
1978 Ponding Adjustment				
Subbasin	Percent Ponding within Subbasin	Location of Ponding within Subbasin	50% Storm Adjustment Factor	4% Storm Adjustment Factor
H1	3.9%	Upper	0.81	0.85
BaC3	0.7%	Upper	0.92	0.94
BoC4	4.2%	Upper	0.81	0.85
LH6	5.0%	Throughout/middle	0.65	0.72
NB2	2.6%	Upper	0.85	0.88
SB2	1.7%	Upper	0.88	0.91
SB3	0.0%		1.00	1.00
SB4	2.2%	Upper	0.86	0.89
SB5	7.7%	Upper	0.78	0.81
SB6	2.0%	Throughout/middle	0.78	0.83
SB7	7.7%	Lower	0.56	0.63

Table A5: Channel Reach Parameters

ID	Reach	Lag (minutes)
R1	Hog Creek, to mouth	873
R2	South Branch Hog Creek, to confluence with North Branch	1204
R3	South Branch Hog Creek, to confluence with Bagley Creek	239
R4	South Branch Hog Creek, to confluence with Bowen Creek	806
R5	South Branch Hog Creek, to gage	212
R6	South Branch Hog Creek, to confluence with Little Hog Creek	752